EARTH DATA
NORTHEAST, INC.

Results of Packer Testing and Geophysical Logging at the Baldwin Hardware Manufacturing Facility

Reading, Berks County, Pennsylvania
September 24, 2004

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FS0287R1.d

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1.0 Introduction

This report describes the results of borehole geophysical logging and packer testing performed by Earth Data Northeast Inc. (Earth Data) at the Baldwin Hardware Manufacturing Facility (the site) Reading, Berks County, Pennsylvania. Geophysical logging and packer testing were conducted during August and September 2004 under the direction and supervision of Loureiro Engineering Associates (Loureiro).

The purpose of the testing was to identify the water bearing zones penetrated by the wells and to determine the yield and water quality of those zones.

2.0 Borehole Geophysical Logging

Background

Earth Data, as a sub-contractor to Loureiro, performed borehole geophysical surveys in 7 monitoring wells at the Baldwin Facility located in Reading, Berks County, Pennsylvania.

Site Geology

The site bedrock is part of the Buffalo Springs Formation. The formation is middle Cambrian in age and is greater than 500 feet thick in many locations. The Buffalo Springs Formation consists mostly of light gray to pinkish-gray interbedded limestone and dolomite, with occasional zones of sand and shale.

Scope of Work

Earth Data performed borehole geophysical logging in a total of 7 wells. The geophysical surveys conducted include the following parameters and methods: natural gamma, caliper, fluid conductivity, fluid temperature, heat-pulse flowmeter and borehole video. This report presents the basic findings of the geophysical investigation. Table 1, displayed below, lists the wells and the surveys performed in each respective well.

Table 1- Scope of Work Summary

	Downhole Television	Fluid Temp. and Conductivity	Caliper	Electric Log	Heat-Pulse Flowmeter
MW-01	X	X	X	X	X
MW-02	X	X	X	X	
MW-03	X	X	X	X	X
MW-04	X	X	X	X	X
MW-05d	X	X	X	X	X
MW-09		X	X	X	X
PS-3	X	X	X	X	

2.1 Description of Geophysical Parameters

Geophysical Log Descriptions

A vertical borehole geophysical survey provides a measure of the physical properties of the borehole, borehole fluid and/or the formation(s) penetrated by the borehole. All noted footage is referenced from top of casing (TOC). Geophysical logs, alone and/or in conjunction with other well construction information, can help to determine geologic and hydrogeologic information pertaining to a borehole and the formations penetrated.

Electric Log

The electric log is a multi electrode tool that measures parameters relating to the flow of electrical currents within the borehole and surrounding material. Due to the nature of this tool, only fluid filled portions of the borehole can be logged. Parameters of the tool used include spontaneous potential, single point resistance and short and long normal resistivity. A brief description of each parameter is provided below:

The **spontaneous-potential** (SP) log reveals the electric potential differences or voltages that can develop at the contacts between dissimilar lithologic units, which are penetrated by the borehole and occasionally at fractures where groundwater is flowing. The measured unit of the SP log is millivolts. Logging equipment consists of two electrodes, one located in the well and one grounded at the surface. Spontaneous potential sources in a borehole include: electrochemical, electro-kinetic/streaming, and oxidation-reduction potentials. Electrochemical effects are probably the most significant source factors, which can be subdivided into membrane and liquid-junction potentials. Both of these effects are the result of the migration of ions from a concentrated solution to a dilute solution. The migration of the ions and their detection is mostly affected by clay or shale, which decreases negative ion (anion) mobility.

The **single-point resistance** (SPR) tool measures the apparent formation resistance in ohms. Logging equipment is the same as that of the SP log. Current flow in some rocks can be contributed to conductive minerals and the surface condition on clay particles. The amount of water and the dissolved constituents in the water will also affect the electric current flow pattern. As a result, the effective porosity of a formation and the interstitial fluid salinity has the greatest effect on the resistance. Typically, a formation with a high sand content will have a high resistance, and a formation with high clay content will have a low resistance. The above relationship is inverse to the voltage response displayed by the spontaneous potential log, where a formation with a high sand content will have a relatively lower potential, and a contact unit with a high clay matrix will have a relatively higher potential.

The **normal-resistivity** tool measures the electrical resistivity of the borehole and surrounding rock. The units measured are ohms-meters. The tool used measures both short and long normal resistivity. The logging equipment consists of five electrodes, three on the tool, one at the top of a 32.8 foot insulated cable and one grounded at the surface. The different spacing of the potential electrodes (16 inches for the short and 64 inches for the long) allows different volumes to be investigated. The volumes investigated are approximately 32 inches and 128 inches in diameter, respectively. Normal resistivity logs commonly are used to measure water quality and formation resistivity. Portions of the borehole that have higher clay content should have a lower resistivity than those with lower clay content.

Common causes of extraneous effects to the electric log are stray electrical currents. Sources of these currents include: electrical storms, corrosion of buried pipelines, railroad tracks, electric motors and other electrical equipment that may be discharging current through a grounded electrode.

Natural Gamma

Natural gamma logs are one of the most widely used geophysical logs in groundwater applications. The primary use of the gamma log is to identify changes in lithology and to determine the relative amounts of clay in the various lithologic units. The measured unit of the natural gamma log is counts per second (cs). The natural gamma photons detected by the gamma log survey will penetrate plastic and steel well casing and screens, however the casing/screen material may reduce received signal. Consequently, natural gamma surveys can be completed inside wells or hollow stem augers. Upon exiting the screen/casing material the log will show an increase in the natural gamma detected.

Caliper

The caliper tool is used to measure the average diameter of the borehole, locate fractures, and determine the cased interval. Three spring-loaded arms act in conjunction to measure the average diameter of the borehole. The caliper logs are collected by first calibrating the tool at the surface by using measuring templates. The caliper tool is then lowered into the borehole to the desired depth, the feeler arms are remotely opened and the borehole is logged in an upward direction from the desired depth to the surface.

Fluid Conductivity

The fluid conductivity log provides borehole fluid electrolytic measurements in microsiemens/centimeter (us/cm). Water with a lower concentration of total dissolved solids will yield a lower fluid conductivity value than water with a high amount of total dissolved solids. Water quality can also influence the fluid conductivity. If enough information is known about contaminants in a well, some conclusions may be drawn using the conductivity log. Fluid conductivity logs will indicate changes in the borehole fluid where water-producing fractures or formations are transmitting water of contrasting composition into or out of the borehole. The fluid conductivity log is usually the first parameter measured and is collected simultaneously with the temperature log.

Fluid Temperature

The fluid temperature log provides a measurement of the temperature of the surrounding air, water or formation in the borehole. Abrupt changes in the slope of the temperature log can indicate where water of differing temperatures and/or quality are entering or exiting the borehole.

Heat-Pulse Flowmeter

The heat-pulse flowmeter is a stationary tool that is placed at pre-selected locations within the borehole to measure the vertical flow, if any, at the given location. Points to measure vertical flow may be selected due to the response of caliper, fluid temperature and/or fluid conductivity logs. Points could also be chosen at fixed intervals to provide a flow profile of the entire borehole. The heat-pulse flow meter is designed for relatively low flow rates (0.33 to 9.84 feet per minute).

The heat-pulse flowmeter consists of a hollow cylinder containing a horizontal wire grid-heating element and thermistors located a fixed distance above and below the grid. As the heat-pulse flow meter is "fired", an electrical current is sent through the high resistance wire grid. The heated borehole fluid migrates with the borehole flow towards one of the thermistors. The tool is equipped with an auto-nulling facility to cancel any offset in thermistor characteristics and return the log trace to a fixed position prior to firing.

The accuracy and reliability of the heat-pulse flowmeter is dependant on borehole conditions. The selected zones are logged down the well to minimize any influence from previous tests. In extremely low flow conditions the heat pulse may alter the natural borehole flow conditions. In high flow areas the heat pulse causes negligible disturbances.

Heat-pulse flowmeter results are presented in graph format. The graph displays the temperature differential between the two thermistors plotted against time in seconds. The temperature differential units are counts per second (cps). The operating software, based on the interpretation point selected by the operator, calculates the fluid speed. In the upper right-hand corner of the graph the fluid speed is misrepresented as feet per minute. The actual units are meters per minute. Fluid speed values displayed in the summary tables for each well are correctly labeled as feet per minute.

3.0 Results of Borehole Geophysical Logging

The basic findings are summarized, by well, below. Copies of the geophysical logs are included in the appendices. The interpreted results of the geophysical logging are focused on: lithologic information, secondary porosity, and fluid properties within each borehole. Lithologic information is based on the natural gamma. Secondary porosity interpretation is based on the caliper, acoustic televiewer, fluid temperature, and fluid conductivity logs and the borehole video survey. The fluid properties are based on the fluid conductivity and fluid temperature logs. Heat-pulse flowmeter results are summarized in table format for each well and the graphs are included in the appendices.

MW-01

Copies of all geophysical logs (caliper, fluid temperature, fluid conductivity, natural gamma, electrical log, and heat-pulse flowmeter graphs) for MW-01 are included in Appendix A. A borehole video survey was also completed at the time of the geophysical logging. The total depth (TD) of the well was observed to be approximately 108' during the borehole video survey. The monitoring well was constructed with 40' of eight-inch steel casing and an open interval from 40' to approximately 108'. At the time of the survey the depth-to-water level (DTW) was observed at approximately 51'.

The caliper log of MW-01 displays a borehole and casing diameter to be 8 inches. As observed on the caliper log the most significant increase in borehole diameter occurs at a depth of approximately 77 feet below TOC. The fluid temperature log displays decreasing fluid temperature with depth. Log responses which may be indicative of fluid entering or exiting the borehole, are noted at depths of approximately 57, 64, 70, 76, 80, 84, 86, and 94 feet below TOC.

The fluid conductivity log displays three areas of differing fluid quality within the well. These areas are approximately 39-82, 82-92, and 92-100 feet below TOC.

The natural gamma log displays an alternating pattern. This pattern may indicate variations of shale occurrence in the formation. The areas displaying higher natural gamma content would be indicative of higher shale occurrence. Increased borehole diameter may also have a log response similar to that of a decrease in shale occurrence.

The electric log parameters (single point resistance, short normal resistivity, and long normal resistivity) also display a similar-alternating pattern. The areas of increased resistivity should correlate with areas of decreased natural gamma content. These areas have the greatest potential of being more transmissive than areas displaying low resistivity and high natural gamma content.

Heat-pulse flowmeter logging was conducted during ambient well conditions at depths of

54', 60', 72', 73', 74', 80', 82', 83', 90', and 98' in this well. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The inconsistent results at depths of 80' and 98' are indicative of no flow or flow below the operating limits of the tool. Table 2a presents a summary of the results.

Table 2a- MW-01 Ambient Heat-Pulse Flowmeter Summary

	Test 1		**Test 2**		**Test 3**	
Depth (ft)	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**
54	N/A	<0.33	N/A	<0.33	Not Tested	
60	N/A	<0.33	N/A	<0.33	Not Tested	
72	N/A	<0.33	Not Tested		Not Tested	
73	N/A	<0.33	Not Tested		Not Tested	
74	N/A	<0.33	N/A	<0.33	Not Tested	
80	Upwards	1.88	N/A	<0.33	Not Tested	
82	N/A	<0.33	Not Tested		Not Tested	
83	N/A	<0.33	Not Tested		Not Tested	
90	N/A	<0.33	N/A	<0.33	Not Tested	
98	N/A	<0.33	Upwards	3.84	Upwards	0.89

Heat-pulse flowmeter logging was conducted during pumping well conditions at depths of 54', 60', 72', 74', 80', 90', and 98'. The pumping rate during the logging was 1.5 gallons per minute (gpm), with approximately 1 foot of drawdown during pumping. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The inconsistent results at depths of 60' and 98' are indicative of no flow or flow below the operating limits of the tool. Table 2b presents a summary of the results.

Table 2b- MW-01 Pumping Heat-Pulse Flowmeter Summary

	Test 1		**Test 2**		**Test 3**	
Depth (ft)	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**
54	N/A	<0.33	N/A	<0.33	Not Tested	
60	Upwards	3.08	N/A	<0.33	N/A	<0.33
72	N/A	<0.33	Not Tested		Not Tested	
74	N/A	<0.33	Not Tested		Not Tested	
80	N/A	<0.33	N/A	<0.33	Not Tested	
90	N/A	<0.33	Not Tested		Not Tested	
98	N/A	<0.33	Upwards	2.25	Not Tested	

MW-02

Copies of all geophysical logs (caliper, fluid temperature, fluid conductivity, natural gamma, and electric) for MW-02 are included in Appendix B. A borehole video survey was also completed at the time of geophysical logging. The TD of the well is reportedly 100', however the TD was not observed in the borehole video survey, due to large amounts of sediment in the borehole at approximately 72'. The monitoring well was constructed with eight-inch steel casing to a depth of approximately 20' and an open interval from 20' to approximately 100'. At the time of the survey, the DTW was approximately 31'.

The caliper log shows an increase in borehole diameter just below the bottom of the casing; this may be due to the over-drilled portion of the borehole into which the casing is set. The more significant features of the caliper log are observed at depths of approximately 39, 44-47, 53, and 57 feet below TOC. More features may be concealed by the roughness of the borehole wall. The caliper log displays decreases in diameter below 76 feet, these decreases may be due to material falling down the well as observed in the borehole video survey.

The fluid temperature log displays decreasing fluid temperature from a depth of approximately 37 to 48 feet, increasing temperature from 48-68 feet and decreasing temperature from 68 feet to the total depth. Log responses which may be indicative of fluid entering or exiting the borehole, are noted at depths of approximately 48, 56, 68, and 89 feet.

The fluid conductivity log displays decreasing conductivity from a depth of approximately 37 to 45 feet, increasing conductivity from 48 to 68 feet, decreasing conductivity from 68 to 94 feet and increasing conductivity from 94 feet to TD.

The natural gamma log displays an alternating pattern. This pattern may indicate variations of shale occurrence in the formation. The areas displaying higher natural gamma content would be indicative of higher shale occurrence. Increased borehole diameter may also have a log response similar to that of a decrease in shale occurrence.

The electric log parameters (single point resistance, short normal resistivity, and long normal resistivity) also display a similar-alternating pattern. The areas of increased resistivity should correlate with areas of decreased natural gamma content. These areas have the greatest potential of being more transmissive than areas displaying low resistivity and high natural gamma content.

MW-03

Copies of all geophysical logs (caliper, fluid temperature, fluid conductivity, natural gamma, electric, and heat-pulse flowmeter graphs) for MW-03 are included in Appendix C. A borehole video survey was also completed at the time of geophysical logging. The TD of the well was observed to be approximately 100' during the borehole video survey. The monitoring well was constructed with eight-inch steel casing to a depth of 20' and an open interval from 20' to approximately 100'. At the time of the survey, the DTW was observed to be approximately 57'. During the television survey, water appeared to be entering the borehole from a fracture above water level, at approximately 51'.

The caliper log of MW-03 displays a borehole and casing diameter to be approximately 8 inches. As observed on the caliper log the most significant increases in borehole diameter occur at depths of approximately 67, 74, 76, 81, 92, 97, and 99 feet.

The fluid temperature log displays decreasing fluid temperature with depth. Log responses which may be indicative of fluid entering or exiting the borehole, are noted at depths of approximately 67, 74, 81, 92, 97, and 99 feet.

The fluid conductivity log displays decreasing fluid conductivity with depth. Log responses which may be indicative of fluid entering or exiting the borehole, are noted at depths of approximately 67, 81, 92, and 99 feet.

The natural gamma log displays an alternating pattern. This pattern may indicate variations of shale occurrence in the formation. The areas displaying higher natural gamma content would be indicative of higher shale occurrence. Increased borehole diameter may also have a log response similar to that of a decrease in shale occurrence.

The electric log parameters (single point resistance, short normal resistivity, and long normal resistivity) also display a similar-alternating pattern. The areas of increased resistivity should correlate with areas of decreased natural gamma content. These areas have the greatest potential of being more transmissive than areas displaying low resistivity and high natural gamma content.

Heat-pulse flowmeter logging was conducted during ambient well conditions at depths of 65', 73', 80', 88', 95', and 100' in this well. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The results of the heat-pulse flowmeter logging do not indicate quantifiable flow with in the monitoring well. Table 3a displays a summary of the logging.

Table 3a- MW- 03 Ambient Heat-Pulse Flowmeter Summary

	Test 1		Test 2		Test 3	
Depth (ft)	Direction	Speed (ft/min)	Direction	Speed (ft/min)	Direction	Speed (ft/min)
65	N/A	<0.33	N/A	<0.33	Not Tested	
73	N/A	<0.33	N/A	<0.33	Not Tested	
80	N/A	<0.33	N/A	<0.33	Not Tested	
88	N/A	<0.33	N/A	<0.33	Not Tested	
95	N/A	<0.33	N/A	<0.33	Not Tested	
100	N/A	<0.33	N/A	<0.33	Not Tested	

Heat-pulse flowmeter logging was conducted during pumping well conditions at depths of 65, 69', 73', 80', 88', 95', and 100'. The pumping rate for the first depth was 0.75 gpm; it was then increased to 1 gpm for the remainder of the logging. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The inconsistent results at depths of 65', 69', and 73' are indicative of no flow or flow below the operating limits of the tool. Table 3b presents a summary of the results.

Table 3b- MW-03 Pumping Heat-Pulse Flowmeter Summary

	Test 1		Test 2		Test 3	
Depth (ft)	Direction	Speed (ft/min)	Direction	Speed (ft/min)	Direction	Speed (ft/min)
65	Upwards	0.45	N/A	<0.33	Not Tested	
69	Upwards	0.79	N/A	<0.33	N/A	<0.33
73	Upwards	0.42	N/A	<0.33	N/A	<0.33
80	N/A	<0.33	N/A	<0.33	Not Tested	
88	N/A	<0.33	N/A	<0.33	Not Tested	
95	N/A	<0.33	N/A	<0.33	Not Tested	
100	N/A	<0.33	N/A	<0.33	Not Tested	

MW-04

Copies of all geophysical logs (caliper, fluid temperature, fluid conductivity, natural gamma, electric, and heat-pulse flowmeter graphs) for MW-04 are included in Appendix D. A borehole video survey was also completed at the time of geophysical logging. The TD of the well was observed to be approximately 97' during the borehole video survey. The monitoring well was constructed with eight-inch steel casing to a depth of 20' and an open interval from 20' to approximately 97'. At the time of the survey, the DTW was observed to be approximately 56'.

The caliper log of MW-04 displays a borehole and casing diameter to be approximately 8 inches. An increase in borehole diameter is observed just below the bottom of the casing, this may be due to the over-drilled portion of the borehole into which the casing is set. As observed on the caliper log the most significant increases in borehole diameter occur at depths of approximately 72, 75, 82-49 and 98 feet.

The fluid temperature log displays decreasing fluid temperature with depth, a slight increase is observed at the bottom portion of the log. The increase may be attributable to material at the bottom of the well. Log responses which may be indicative of fluid entering or exiting the borehole, are noted at depths of approximately 90 and 98 feet.

The fluid conductivity log displays increasing in fluid conductivity from a depth of approximately 57 to 68 feet decreasing conductivity from 68 to 98 feet and a small area of increasing conductivity from 98 to TD of the well. Log responses, which may be indicative of fluid entering or exiting the borehole, are noted at depths of approximately 64, 68, 72, 76, and 98.

The natural gamma log displays an alternating pattern. This pattern may indicate variations of shale occurrence in the formation. The areas displaying higher natural gamma content would be indicative of higher shale occurrence. Increased borehole diameter may also have a log response similar to that of a decrease in shale occurrence.

The electric log parameters (single point resistance, short normal resistivity, and long normal resistivity) also display a similar-alternating pattern. The areas of increased resistivity should correlate with areas of decreased natural gamma content. These areas have the greatest potential of being more transmissive than areas displaying low resistivity and high natural gamma content.

Heat-pulse flowmeter logging was conducted during ambient well conditions at depths of 60', 70', 80', 90', and 100' in this well. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The results of the heat-pulse flowmeter logging at 70' and 90' are indicative of an upward gradient at this depth. The inconsistent results at 60', 80', and 100' are indicative of no flow or flow below the operating limits of the tool. Table 4a presents a summary of the results.

Table 4a- MW-04 Ambient Heat-Pulse Flowmeter Summary

	Test 1		Test 2		Test 3	
Depth (ft)	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**
60	N/A	<0.33	N/A	<0.33	N/A	<0.33
70	Upwards	0.54	Upwards	4.08	Upwards	4.73
80	N/A	<0.33	Upwards	2.17	Upwards	4.27
90	Upwards	5.83	Upwards	2.13	Upwards	5.57
100	N/A	<0.33	Upwards	5.41	N/A	<0.33

Heat-pulse flowmeter logging was conducted during pumping well conditions at depths of 60', 70', 80', 90', and 100'. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The results of the heat-pulse flowmeter logging at all depths are indicative of an upward gradient in this borehole. Table 4b presents a summary of the results.

Table 4b- MW-04 Pumping Heat-Pulse Flowmeter Summary

	Test 1		Test 2		Test 3	
Depth (ft)	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**
60	Upwards	3.35	Upwards	3.34	Upwards	6.19
70	Upwards	2.08	Upwards	2.74	Upwards	0.54
80	Upwards	4.67	Upwards	1.33	N/A	<0.33
90	N/A	<0.33	Upwards	3.34	Upwards	1.33
100	Upwards	3.50	Upwards	5.41	Not Tested	

MW-05d

Copies of all geophysical logs (caliper, fluid temperature, fluid conductivity, natural gamma, electric, and heat-pulse flowmeter graphs) for MW-05d are included in Appendix E. A borehole video survey was also completed at the time of geophysical logging. The TD of the well was observed to be approximately 200' during the borehole video survey. The monitoring well was constructed with six-inch steel casing to a depth of 40' and an open interval from 40' to approximately 200'. At the time of the survey, the DTW was observed to be approximately 69.5'. During the television survey, water appeared to be entering the borehole from a fracture above water level, at approximately 49.6'.

The caliper log of MW-05 displays a casing diameter of 6 inches and a borehole diameter of less than 5.5 inches. As observed on the caliper log the most significant increases in borehole diameter occur at depths of approximately 86, 95, 104, 118, and 153 feet.

The fluid temperature log displays decreasing fluid temperature with depth. The temperature log displays at several areas of differing fluid quality within the well. The most significant change in fluid temperature is located at approximately 152 feet; other noted areas are 86, 95, 104, and 127.

The fluid conductivity log displays several areas of differing fluid quality within the well. They are approximately 70-96, 96-112, 112-118, 118-133, 133-152, 152-192, and 192-TD.

The natural gamma log displays an alternating pattern. This pattern may indicate variations of shale occurrence in the formation. The areas displaying higher natural gamma content would be indicative of higher shale occurrence. Increased borehole diameter may also have a log response similar to that of a decrease in shale occurrence.

The electric log parameters (single point resistance, short normal resistivity, and long normal resistivity) also display a similar-alternating pattern. The areas of increased resistivity should correlate with areas of decreased natural gamma content. These areas have the greatest potential of being more transmissive than areas displaying low resistivity and high natural gamma content.

Heat-pulse flowmeter logging was conducted during ambient well conditions at depths of 76', 81', 90', 102', 110', 116', 124', 146', 150', 151', 152', 156', 175', 190', and 200' in this well. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The results of the heat-pulse flowmeter logging at 90', 116', 156', and 175' are indicative of an upward gradient at these depths. The inconsistent results at the remaining depths are indicative of no flow or flow below the operating limits of the tool. Table 5a presents a summary of the results.

Table 5a- MW-05d Ambient Heat-Pulse Flowmeter Summary

	Test 1		Test 2		Test 3	
Depth (ft)	**Direction**	**Speed (ft/min)**	**Direction**	**Depth (ft)**	**Direction**	**Speed (ft/min)**
76	N/A	<0.33	N/A	<0.33	N/A	<0.33
81	N/A	<0.33	N/A	<0.33	Not Tested	
90	N/A	<0.33	Upwards	2.69	Upwards	1.36
102	N/A	<0.33	N/A	<0.33	N/A	<0.33
110	N/A	<0.33	N/A	<0.33	N/A	<0.33
116	Upwards	3.90	Upwards	0.76	Upwards	0.95
124	N/A	<0.33	N/A	<0.33	Upwards	1.12
146	N/A	<0.33	Upwards	0.57	N/A	<0.33
150	N/A	<0.33	N/A	<0.33	N/A	<0.33
151	N/A	<0.33	Not Tested		Not Tested	
152	N/A	<0.33	N/A	<0.33	N/A	<0.33
156	Upwards	1.69	Upwards	1.22	Upwards	1.54
175	Upwards	2.25	Upwards	1.18	Upwards	1.80
190	N/A	<0.33	N/A	<0.33	Not Tested	
200	N/A	<0.33	N/A	<0.33	Not Tested	

Heat-pulse flowmeter logging was conducted during pumping well conditions at depths of 75.5', 81', 90', 102', 110', 116', 124', 146', 152', 156', 175', 190', and 200'. The pumping rate during the logging was 2.0 gpm. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The results of the heat-pulse flowmeter logging 90', 102', 110', 116', 124', 146', 152', 156', and 175' indicate an upward gradient at these depths. The inconsistent results at 75.5', 81', 190', and 200' are indicative of no flow or flow below the operating limits of the tool. Table 5b presents a summary of the results.

Table 5b- MW-05d Pumping Heat-Pulse Flowmeter Summary

	Test 1		Test 2		Test 3	
Depth (ft)	**Direction**	**Speed (ft/min)**	**Direction**	**Depth (ft)**	**Direction**	**Speed (ft/min)**
75.5	Upwards	2.13	Not Tested		Not Tested	
81	N/A	<0.33	Not Tested		Not Tested	
90	Upwards	9.92	Not Tested		Not Tested	
102	Upwards	9.73	Not Tested		Not Tested	
110	Upwards	8.85	Upwards	9.19	Not Tested	
116	Upwards	8.85	Upwards	8.85	Not Tested	
124	Upwards	7.71	Upwards	7.00	Not Tested	
146	Upwards	8.11	Upwards	8.11	Not Tested	
152	Upwards	5.49	N/A	<0.33	Not Tested	
156	Upwards	2.13	Upwards	1.08	Not Tested	
175	Upwards	3.96	Upwards	2.17	Not Tested	
190	Upwards	2.93	N/A	<0.33	Not Tested	
200	N/A	<0.33	Not Tested		Not Tested	

MW-09

Copies of all geophysical logs (caliper, fluid temperature, fluid conductivity, natural gamma, electric, and heat-pulse flowmeter graphs) for MW-09 are included in Appendix F. A borehole video survey was not completed in this well. During geophysical logging, the TD of the well was observed to be approximately 100'. The caliper log displays eight-inch casing to an approximate depth of 25' and an open interval from 25' to approximately 100'. The fluid temperature and fluid conductivity logs show the DTW to be approximately 52' during the time of geophysical logging.

The caliper log of MW-09 displays a casing and borehole diameter of approximately 8 inches. As observed on the caliper log the most significant increases in borehole diameter occur at depths of approximately 53-58, 63, 66-68, and 88 feet.

The fluid temperature log displays decreasing fluid temperature with depth. The temperature log displays at several areas of differing fluid quality within the well. The most significant change in fluid temperature is located at approximately 67 feet; other noted areas are 63, 79, 82, and 94.

The fluid conductivity log displays a significant increase at a depth of 67 feet. Other areas of interest are 78, 86, and 90.

The natural gamma log displays an alternating pattern. This pattern may indicate variations of shale occurrence in the formation. The areas displaying higher natural gamma content would be indicative of higher shale occurrence. Increased borehole diameter may also have a log response similar to that of a decrease in shale occurrence.

The electric log parameters (single point resistance, short normal resistivity, and long normal resistivity) also display a similar-alternating pattern. The areas of increased resistivity should correlate with areas of decreased natural gamma content. These areas have the greatest potential of being more transmissive than areas displaying low resistivity and high natural gamma content.

Heat-pulse flowmeter logging was conducted during ambient well conditions at depths of 69', 74', 79', 86', and 94' in this well. The depths were selected based on fluid temperature, fluid conductivity, and caliper logs. The inconsistent results in this borehole are indicative of no flow or flow below the operating limits of the tool. Table 6 presents a summary of the results.

Table 6 – MW-09 Heat-Pulse Flowmeter Summary

	Test 1		Test 2		Test 3	
Depth (ft)	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**	**Direction**	**Speed (ft/min)**
69	N/A	<0.33	N/A	<0.33	Not Tested	
74	N/A	<0.33	N/A	<0.33	Not Tested	
79	N/A	<0.33	N/A	<0.33	Not Tested	
86	Upwards	0.51	N/A	<0.33	N/A	<0.33
94	Upwards	3.34	N/A	<0.33	Upwards	1.02

PS-3

Copies of all geophysical logs (caliper, fluid temperature, fluid conductivity, natural gamma, and electric) for PS-3 are included in Appendix G. A borehole video survey was also completed at the time of geophysical logging. The TD of the well was observed to be approximately 554' during the borehole video survey. The monitoring well was constructed with eight-inch steel casing to a depth of 99' and an open interval from 99' to approximately 554'. At the time of the survey, the DTW was observed to be approximately 23'.

The caliper log of MW-09 displays a casing and borehole diameter of approximately 8 inches. As observed on the caliper log the most significant increases in borehole diameter occur at depths of approximately 165-172, 173-179, 193-205, 210, 221, 233, 273, 292, 329, 348, 397, 534, 538, and 552-558 feet.

The fluid temperature log displays decreasing fluid temperature with depth. The temperature log displays very few areas of differing fluid temperature within the well. The most significant change in fluid temperature is located at approximately 110 feet; other noted areas are 142, 185, 233, 329, and 370.

The fluid conductivity log displays increasing fluid conductivity from 103-107, decreasing fluid conductivity from 107-370, increasing fluid conductivity from 370-433, decreasing conductivity from 433-508, and increasing fluid conductivity from 508-558 feet.

The natural gamma log displays an alternating pattern. This pattern may indicate variations of shale occurrence in the formation. The areas displaying higher natural gamma content would be indicative of higher shale occurrence. Increased borehole diameter may also have a log response similar to that of a decrease in shale occurrence.

The electric log parameters (single point resistance, short normal resistivity, and long normal resistivity) also display a similar-alternating pattern. The areas of increased resistivity should correlate with areas of decreased natural gamma content. These areas have the greatest potential of being more transmissive than areas displaying low resistivity and high natural gamma content.

4.0 Packer Testing

Packer testing was conducted in seven boreholes, MW-01, MW-02, MW-03, MW-04, MW-05D, MW-09, and PS-3, at the direction of Loureiro. The purpose of the testing was to identify the water-bearing zones and collect water quality samples from those intervals.

Intervals selected within the borehole were isolated from the remaining open bedrock borehole by means of a straddle packer assembly. Durable, natural rubber-coated bladders were inflated with nitrogen in order to expand each packer's diameter to form a seal against the borehole wall. Within these isolated borehole segments, measurements of hydraulic gradient were recorded and discrete water quality samples were collected for laboratory analysis.

All water quality samples were collected by Loureiro and analyzed by their subcontracted laboratory. This data is not contained in this report.

4.1 Description of Equipment

The packer testing system used onsite utilized single packer and straddle packer assemblies with an integrated check-valve, as generally depicted in diagrams presented in the Appendix of this report. The following describes the components of the systems used on this project.

Packers

Nitrogen-inflated packers set on 2.0-inch diameter, schedule 40 galvanized lift pipes.

Packer diameters:	3.5 inches (uninflated)/ 6.2 inches (maximum inflation) 5.4 inches (uninflated/ 10.5 inches (maximum inflation)
Packer lengths:	3.4 feet 4.0 feet

Pumps

Goulds 18E154 1.5 HP Submersible Pump

Goulds 25EL504 5.0 HP Submersible Pump

Grundfos Rediflo Submersible Pump

Data Collection System

Three pressure transducers (20 mA @ 200 psi) calibrated to read depth to water, allowed for the continuous monitoring of water levels above, within and below each interval tested. PS-3 required the use of three pressure transducers (30 mA @ 300psi) calibrated to read depth to water because of greater operational depth.

Transducer signals were directed to a digital data logger.

The data logger output was directed to a field computer, which provided a real time, tabular or graphic display of the water level data.

4.2 Packer Testing Procedure

The packer testing procedure was as follows:

1. Packer assembly was lowered into the borehole to the desired depth.

2. Pressure transducers were activated and initial millivolt readings were obtained.

3. Millivolt readings from each transducer were converted to read depth to water level from ground surface prior to packer inflation. Data logging was initiated.

4. Nitrogen was introduced through the inflation tubes to each packer causing the packers to expand outward against the wall of the borehole.

5. Once the packers were inflated, the transducer readings were allowed to equilibrate, revealing head pressure differential values between borehole segments. These were noted.

6. The pump was powered on by a generator at the surface and controlled by a pump control box. The pumping rate was adjusted using a valve on the discharge assembly, and the zone was pumped at a rate that could provide consistent flow. When possible a volume of groundwater equal to 3 interval volumes were removed.

7. Groundwater sampling was conducted utilizing the Grundfos Rediflo, inserted in the Lift Pipe or down the casing.

8. The pump was turned off and the water level in the isolated interval was allowed to recover.

10. All field equipment was decontaminated. Galvanized steel lift pipe, packers and cable reel were physically scrubbed with a mixture of Liquinox and distilled water, thoroughly steam cleaned and allowed to air dry. All packers and lift pipe sections were steam cleaned internally as well as externally. Temperature-sensitive pressure transducers were cleaned with a Liquinox and distilled water scrub and allowed to air dry.

4.3 Summary of MW-01 Packer Test

The borehole, MW-01 was constructed as an 8.0-inch diameter open borehole drilled to a depth of 100 feet below top of casing (BTOC). Eight-inch diameter steel casing extends to an approximate depth of 40 feet BTOC.

Water level measurements taken during the testing of this well were made from the top of the casing. For reporting purposes, water level values discussed in this text were taken from logged data, not from field observations. The report appendix contains all packer test data and field notes.

4.3.1 Zone #1-Interval: SWL - 71'

Zone 1 was tested on August 20, 2004. The borehole segment from SWL to 71.0' BTOC was tested by inflating the single packer assembly. Prior to the inflation of the packer, the static water level of the borehole was 50.71'. Following the inflation of the packer, water levels within and below the interval were 50.15' and 50.86', respectively. Prior to pumping the zone, water levels in the pumping and lower intervals were 50.24' and 50.86' respectively.

The interval was pumped at a rate of 3.0 gpm for approximately nineteen (19) minutes. The pumping rate was backed-off to 2.5 gpm at this point and pumped at this rate for one (1) minute. It was backed-off further to 2.0 gpm, and pumping continued at this rate for twenty-three (23) minutes before the pump was shut off.

At the cessation of pumping water levels in the pumping zone and the lower zone were 55.13' and 51.13' BTOC, respectively.

No discharge water was allowed to reenter the isolated interval due to the integrated check-valve on the pump. During the discussion of this zone, recovery will refer to the period following the cessation of pumping.

The zone was allowed to recover for approximately fourteen (14) minutes at which time the zone recovered approximately 88% of the pre-pumping level.

4.3.2 Zone #2-Interval: 75.0' - TD

Zone 2 was tested on August 20, 2004. The segment of borehole from 75.0'-TD was tested using a single packer assembly. Prior to the inflation of the packer, the static water level in the borehole was 50.37' BTOC. Following the inflation of packers, water levels in the upper and pumping zone were 50.28' and 50.63' BTOC, respectively. Prior to pumping the zone, water levels in the upper and pumping intervals were 49.66' and 50.65' respectively.

The zone was pumped at a rate of 3.0 gpm for approximately four (4) minutes. The pump was increased to a rate of 6.0 gpm. The zone was pumped at this rate for three (3) minutes before the pump was increased to 18.0 gpm. The zone was pumped at this rate for one (1) minute until the pump was shut-off. The pump was restarted two (2) minutes later and immediately stopped. The pump was turned on and backed-off to 6.0 gpm until the pump was shut-off.

At the cessation of pumping water levels in the upper and pumping zones were 49.31' and 51.18' BTOC, respectively. The zone was allowed to recover for approximately twelve (12) minutes at which time the zone recovered 26% of the pre-pumping level.

4.4 Summary of MW-02 Packer Test

The borehole, MW-02 was constructed as an 8.0-inch diameter open borehole drilled to a depth of 100 feet BTOC. Eight-inch diameter steel casing extends to an approximate depth of 19 feet BTOC.

MW-02 was tested using a 5.4-inch packer assembly in two zones.

Water level measurements taken during the testing of all onsite wells were made from top of casing. For reporting purposes, water level values discussed in this text were taken from logged data, not from field observations. The report appendix contains all packer test data and field notes.

4.4.1 Zone #1-Interval: SWL - 69.0'

Zone 1 was tested on August 23, 2004. The borehole segment from SWL-69.0' BTOC was tested by inflating the single packer assembly. Prior to the inflation of the packer, the static water level of the borehole was 31.91'. Following the inflation of the packer, water levels in the pumping zone and lower interval were 31.91' and 33.34', respectively. Prior to pumping the zone, water levels in the pumping and lower intervals were 32.02' and 35.08', respectively.

Zone 1 was pumped at a rate of 2.0 gpm for two (2) minutes. The rate was then increased to 2.5 gpm for one (1) minute and then increased to 3.0 gpm for a duration of sixteen (16) minutes. At this time, the pumping rate was then increased to 3.15 gpm until the pump was shut-off.

At the cessation of pumping, water levels in the pumping and lower zones were 31.85' and 36.05' BTOC respectively. Zone 1 was allowed to recover three (3) minutes, at which time the water level recovered 100% of the pre-pumping level.

4.4.2 Zone #2-Interval: 73.0' - TD

Zone 2 was tested on August 23, 2004. The segment of borehole from 73.0' to TD BTOC was tested using a single packer assembly. The packer was already inflated from the testing of zone 1 in this borehole. Prior to pumping water levels in the upper and pumping zone were 31.92' and 36.67' BTOC, respectively.

Zone 2 was pumped at rate of 4.0 gpm for five (5) minutes. The rate had decreased to 3.9 gpm at this time. Five (5) minutes later, it had fallen to 3.8 gpm; this rate was maintained until the pump was shut-off.

At the cessation of pumping, the water levels in the upper and pumping zone were 31.98' and 81.57' BTOC, respectively.

Zone 2 was allowed to recover twenty-three (23) minutes at which time the water level recovered 64% of the pre-pumping level.

4.5 Summary of MW-03 Packer Test

The borehole, MW-03 was constructed as an 8.0-inch diameter open borehole drilled to a depth of 100 feet BTOC. Eight-inch diameter steel casing extends to an approximate depth of 19 feet BTOC.

MW-03 was tested using a 5.4-inch packer assembly in two zones.

Water level measurements taken during the testing of all onsite wells were made from top of casing. For reporting purposes, water level values discussed in this text were taken from logged data, not from field observations. The report appendix contains all packer test data and field notes.

4.5.1 Zone #1-Interval: SWL - 83.0'

Zone 1 was tested on August 24, 2004. The borehole segment from SWL-83.0' BTOC was tested by inflating the single packer assembly. Prior to the inflation of the packer, the static water level of the borehole was 57.76'. Following the inflation of the packer, water levels in the pumping zone and lower interval were 55.57' and 57.97' BTOC, respectively. Prior to pumping the zone, water levels in the pumping and lower intervals were 55.45' and 58.08' BTOC respectively.

Zone 1 was pumped at an initial rate of 1.0 gpm for seven (7) minutes. It was then increased to a rate of 2.0 gpm for fifteen (15) minutes. Nine (9) minutes later, the rate had fallen to 1.3 gpm. The rate was decreased to 1.0 gpm for two (2) minutes; it was decreased again two (2) minutes to 0.85 gpm. After a minute, the rate was decreased a final time to 0.65 gpm, which the interval maintained until the pump was shut-off.

At the cessation of pumping, water levels in the pumping and lower zones were 71.07' and 58.48' BTOC respectively. Zone 1 was allowed to recover eleven (11) minutes, at which time the water level recovered 18% of the pre-pumping level.

4.5.2 Zone #2-Interval: 87.0' - TD

Zone 2 was tested on August 24, 2004. Prior to the inflation of the packer, the static water level of the borehole was 57.01' BTOC. Following the inflation of the packer, water levels in the upper interval and pumping zone were 53.15' and 54.84' BTOC, respectively. Prior to pumping the zone, water levels in the pumping and lower intervals were 52.50' and 54.73' BTOC, respectively.

Zone 2 was pumped at rate of 0.9 gpm for two (2) minutes before it was increased to 2.4 gpm for three (3) minutes. The rate was increased to 4.25 gpm for five (5) minutes and then the rate was raised to 5.8 gpm. Eight (8) minutes later the rate was decreased to 5.75 gpm, and a minute later it was decreased to 5.3 gpm. After two (2) minutes the rate was lowered to 5.0 gpm; this rate was maintained until the pump was shut-off.

At the cessation of pumping, the water levels in the upper and pumping zone were 51.55' and 60.14' BTOC, respectively.

Zone 2 was allowed to recover thirteen (13) minutes at which time the water level recovered 73% of the pre-pumping level.

4.6 Summary of MW-04 Packer Test

The borehole, MW-04 was constructed as an 8.0-inch diameter open borehole drilled to a depth of 100 feet BTOC. Eight-inch diameter steel casing extends to an approximate depth of 19 feet BTOC.

MW-04 was tested using a 5.4-inch packer assembly in two zones.

Water level measurements taken during the testing of all onsite wells were made from top of casing. For reporting purposes, water level values discussed in this text were taken from logged data, not from field observations. The report appendix contains all packer test data and field notes.

4.6.1 Zone #1-Interval: SWL - 68.0'

Zone 1 was tested on August 24, 2004. The borehole segment from SWL-68.0' BTOC was tested by inflating the single packer assembly. Prior to the inflation of the packer, the static water level of the borehole was 54.56'. Following the inflation of the packer, water levels in the pumping zone and lower interval were 52.43' and 55.44' BTOC, respectively. Prior to pumping the zone, water levels in the pumping and lower intervals were 52.75' and 55.65' BTOC respectively.

Zone 1 was pumped at a rate of 1.1 gpm for eleven (11), at which time the zone dewatered. The zone was allowed to recover for six minutes before the pump was turned on again to collect a sample.

At the cessation of pumping, water levels in the pumping and lower zones were 58.06' and 56.36' BTOC respectively. Zone 1 was allowed to recover ten (10) minutes, at which time the water level recovered 24%.

4.6.2 Zone #2-Interval: 72.0' - TD

Zone 2 was tested on August 24, 2004. The segment of borehole from 72.0' to TD BTOC was tested using a single packer assembly. The packer was already inflated from the testing of zone 1. Prior to pumping, water levels in the upper and pumping zone were 56.17' and 56.34' BTOC, respectively.

Zone 2 was pumped at rate of 1.0 gpm for nine (9) minutes. The rate was then increased to 2.6 gpm for six (6) minutes, and then pumped at a reduced rate of 2.2 gpm for nine (9) minutes. The rate was decreased to 2.0 gpm, and the rate steadily fell off at this point until it reached 1.75 gpm three (3) minutes later. The rate was increased to 1.9 gpm, and this rate was maintained until the pump was shut-off.

At the cessation of pumping, the water levels in the upper and pumping zone were 55.67’ and 81.46’ BTOC, respectively.

Zone 2 was allowed to recover eighteen (18) minutes at which time the water level recovered 93% of the pre-pumping level.